IMPROVING AEROSOL RETRIEVALS BY USING MULTI-MODAL REPRESENTATIONS OF THE LAND SURFACE REFLECTANCE TIME SERIES: THE MULTIMODAL TEMPORAL AEROSOL RETRIEVAL (MTAR) ALGORITHM

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Abstract

We developed a multi-temporal algorithm to retrieve aerosol from the time series of retrieved surface reflectances. Our previously developed Empirical Orthogonal Functions algorithm is used as a first-guess to retrieve the initial time series of surface reflectances at single pixel resolution (500 m on MODIS). Then, a multi-modal distribution is used to model this time-series and the pixel's BRDF distribution is used to retrieve histograms of the optical depth for each day. In addition, a relaxed minimum reflectivity constraint is borrowed from MAIAC and is used to filter the optical depth histograms. Finally, the optical depth histograms and associated fine/coarse ratio vectors are spatially smoothed using a 7-by-7 filter window to generate the final optical depth product.

Some benefits of the algorithm are:

- **Large improvement over deserts, such as Solar Village, Saudi Arabia, compared to the MAIAC algorithm, which is the current state-of-the-art multitemporal aerosol algorithm**
- **Significant improvement over urban areas, such as CCNY, as compared to Dark Target (DT), current NASA operational algorithm for vegetation, and comparable performance to MAIAC**
- **Has large potential for bright surface retrievals on GOES-R and VIIRS**
  - **Advantages for both VIIRS and GOES-R in desert because we are outperforming state-of-the-art MAIAC algorithm**
  - **MAIAC may not be optimal on GOES-R due to the different tradeoff between angular and temporal sampling**
  - **MTAR algorithm urban performance on GOES-R may exceed that of MAIAC because MTAR algorithm is capable of incorporating large numbers of noisy temporal samples**

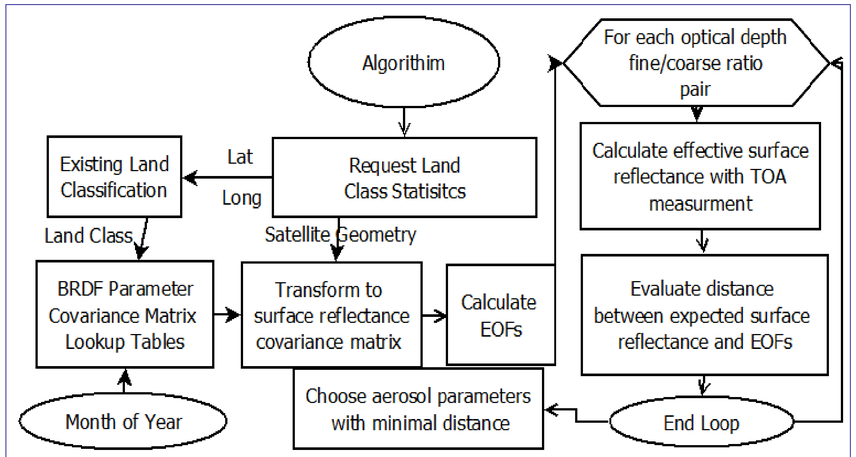
Illustration of MAIAC Minimum Reflectivity Constraint

	$\tau = 0$	$\tau = 0.05$	$\tau = 0.1$	$\tau = 0.15$	$\tau = 0.2$	$\tau = 0.25$
Day 1	0.6	0.56	0.48	0.45	0.44	0.41
Day 2	0.48	0.45	0.41	0.39	0.35	0.20
Day 3	0.56	0.48	0.45	0.41	0.27	0.10
Day 4	0.52	0.51	0.48	0.45	0.43	0.41
Day 5	0.7	0.6	0.56	0.48	0.47	0.45

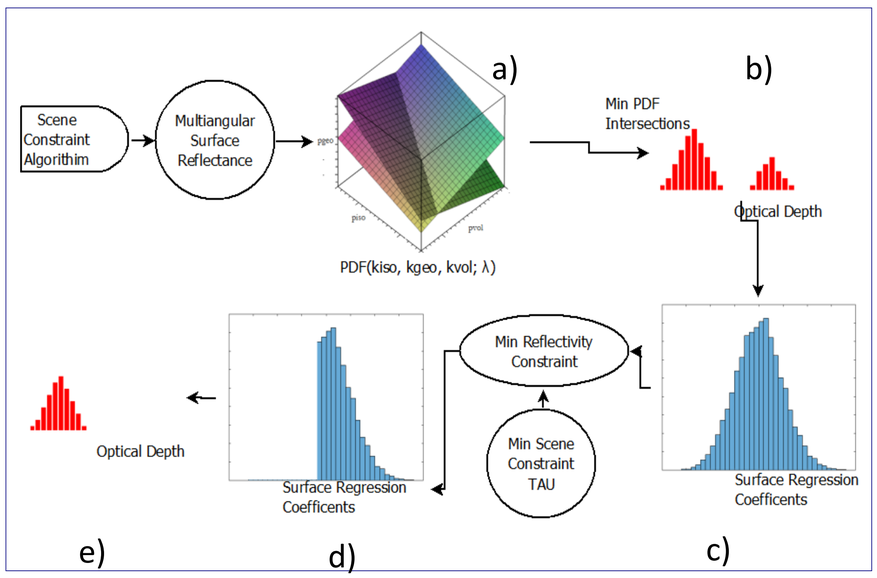
MAIAC Minimum Reflectivity Constraint

- MAIAC algorithm works by stating that the SRC should remain constant for 16 days and by matching SRC coefficients between days to retrieve days
- For MAIAC, SRC $= \frac{p_{466}}{p_{2120}}$
- If SRC was determined to be 0.45, retrieved optical depth for each day would be yellow cell
- SRC determined from clearest day, which has lowest SRC at $\tau = 0$. This is Day 2 in the above example. Optical depth on that day (τ_0) is determined by increasing it from zero and forward modelling for all days on 20 km box until minimum RMSE is reached
- Once τ_0 is determined at 20 km, SRCs and optical depths become known at 1 km, which is the resolution of the final product

First-Guess Algorithm Flow Chart (Empirical Orthogonal Functions)



MTAR Algorithm Flowchart



MTAR Algorithm Description

a) Estimate the PDF of each pixel's BRDF by drawing a plane in BRDF parameter space for each historical EOF algorithm retrieved surface reflectance for pixel using $p_s = k_{iso} + k_{geo} f_{geo} + k_{vol} f_{vol}$

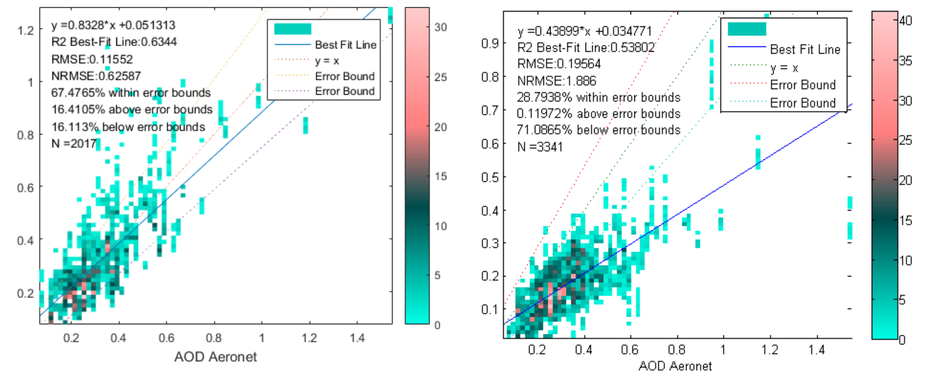
b) Calculate optical depth histogram and associated fine/coarse ratio vector for each pixel for each day by taking minimum number of maximum PDF intersections for each band for each optical depth bin

c) Convert optical depth histograms for each day to SRC histogram for all days

d) Remove all SRCs less than 90% of effective SRC for minimum EOF retrieved optical depth. This is a relaxed version of MAIAC Minimum Reflectivity Constraint (see above)

e) Convert filtered SRC histogram back to optical depth histograms and spatially average in 7x7 windows to get final product. Final product quality controlled by threshold on best optical depth histogram bin value

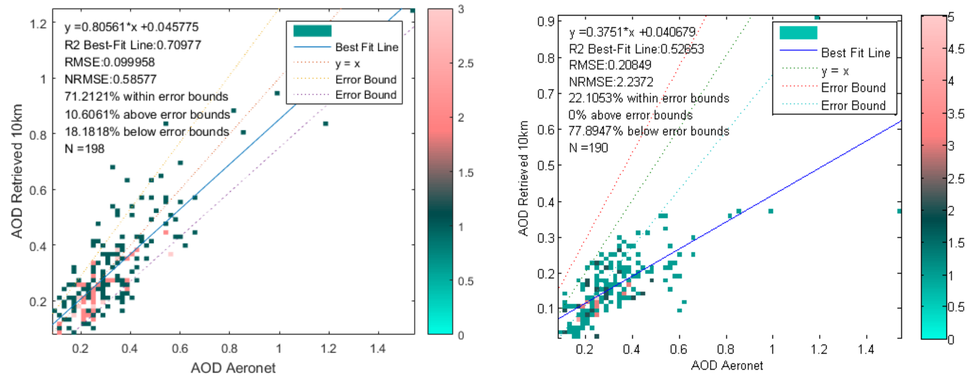
Retrieval Results (Solar Village, Saudi Arabia)



Colorbar represents number of points in 2-d bin

Figure 1a: Comparison of MTAR algorithm to AERONET at the Solar Village site at 3km resolution for the aerosol optical depth retrieved at 550 nm

Figure 1b: Comparison of MAIAC algorithm to AERONET at the Solar Village site at 3km resolution for the aerosol optical depth retrieved at 550 nm



Colorbar represents number of points in 2-d bin

Figure 2a: 10.5 km daily average MTAR aerosol optical depth retrieval versus AERONET on days where more than 70 % of pixels were retrieved by the MTAR algorithm

Figure 2b: 10.5 km daily average MAIAC aerosol optical depth retrieval versus AERONET on days where more than 70 % of pixels were retrieved by the MTAR algorithm and the MAIAC algorithm

Retrieval Results (CCNY)

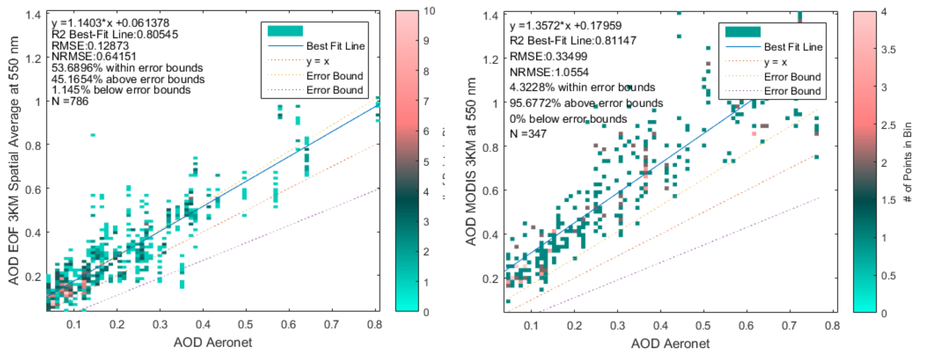
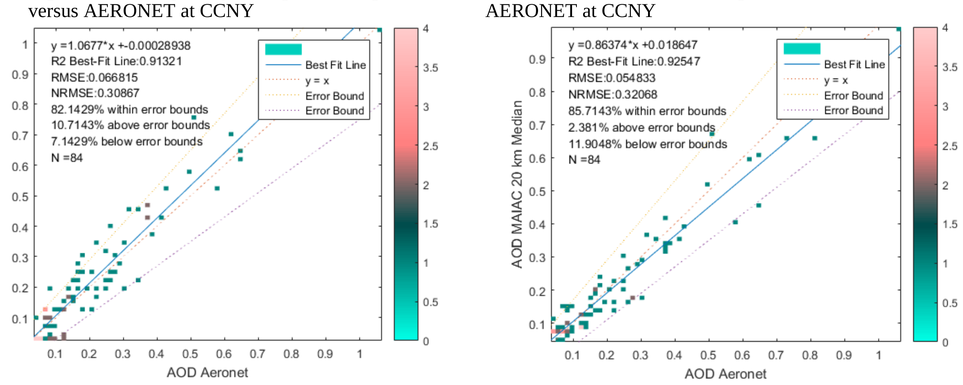


Figure 3a: 3 km spatially-averaged EOF algorithm versus AERONET at CCNY

Figure 3b: 3 km MODIS DT algorithm versus AERONET at CCNY



Colorbar represents number of points in 2-d bin

Figure 4a: 20 km median MTAR aerosol optical depth retrieval versus AERONET

Figure 4b: 20 km median MAIAC aerosol optical depth retrieval versus AERONET when MTAR retrievals were performed

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